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Laser-Induced Back-Ablation of Aluminum Thin Films using Ultra-Short Laser Pulses

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We describe the novel application of ultrashort laser pulses to laser-induced back-ablation. Production of "flyer-plate" type vapor plumes of high density and directivity is observed. Characteristic plume light emission is long lived.

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Conventional laser-induced front ablation at metal/vacuum interfaces is a well-known and successful technique used in processes such as pulsed laser deposition (PLD). By contrast, Laser-Induced Back-Ablation (LIBA) is a process in which a laser pulse propagates through a transparent substrate (i.e. glass) and interacts with a metal thin film at the glass/metal interface (see figure 1). This ablation can result in different metal vapor plumes than are produced by conventional laser ablation. We use 700 fsec laser pulses to both produce and probe ablated aluminum, and to our knowledge, this is the first application of ultra-short pulse technology to LIBA.

Our study uses the Picosecond Laser system in the Janus Laser Facility at Lawrence Livermore National Laboratory. We used laser pulses of duration 700 fsec at 1053 nm with energy between 6-52 mJ. A small fraction of each pulse is redirected and delayed for use as a probe. The laser ablation pulse is focused down with an off-axis parabola ($f/5$) to a spot size of 1 mm at the glass/aluminum interface. The probe pulse propagates transversely through the plume, producing a shadowgraph. We also placed a CCD camera (Hitachi KP-140) directly above the target and perpendicular to the propagation of the ablation and probe pulses. The camera captures time-integrated, spatially resolved images of the light emission from the plume both in flight and during redeposition onto a working substrate. The working substrate (i.e. glass slide) was placed 1.63 cm behind the aluminum thin film target to recollect the plume.

The ablated aluminum plume is observed to be visibly well-localized (see figure 2) for ablation fluence above 0.76 J/cm^2. These localized aluminum plumes, or "flyer plates", are necessarily of high density (of order $10^{19} cm^{-3}$), have velocities of order 10^5 cm/s, and have long-lived light emission (of order microseconds). The time-integrated images of light emitted from the flyer plate indicate that the flyer plate has a low divergence. Redepositions of flyer plates on the working substrate confirm a full divergence full angle $\approx 4^o$. This redeposited material adheres strongly to the working substrate and passes the adhesion "Scotch-Tape" test. The combination of high directivity and high adhesion are well-suited to applications such as selective metal deposition (i.e. bonding, which we have previously demonstrated using LIBA with nanosecond laser pulses). Our work in this application is ongoing, and initial results will be presented.

A. B. Bullock, P.R. Bolton, F. J. Mayer, and R. S. Walling, Laser-Induced Back-Ablation of Aluminum Thin Films using Ultra-Short Pulses

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Figure 1. Laser-Induced Back-Ablation (LIBA) Geometry. The Al film ($0.5 \mu m$ thick) is ablated by a 700 fsec, 1053 nm pulse with a spot size of 1 mm.

Figure 2. Shadowgraph of "Flyer Plate". The flyer plate has a diameter $d \approx 700 \mu m$, a thickness $t \approx 300 \mu m$, and a density $\rho \approx 10^{19} cm^{-3}$.

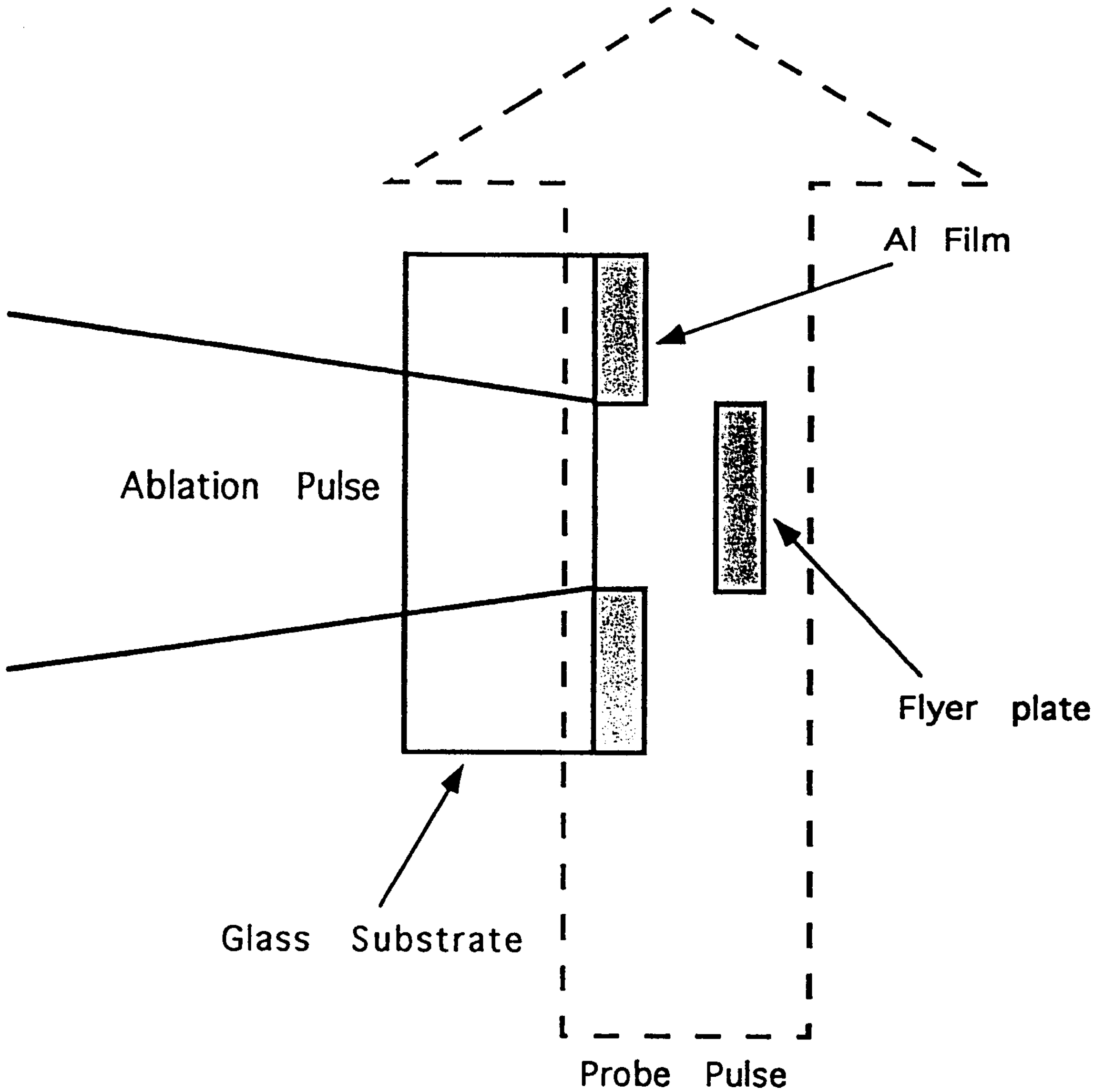
Al Film
Ablation Pulse
Flyer plate
Glass Substrate
Probe Pulse

Figure 1

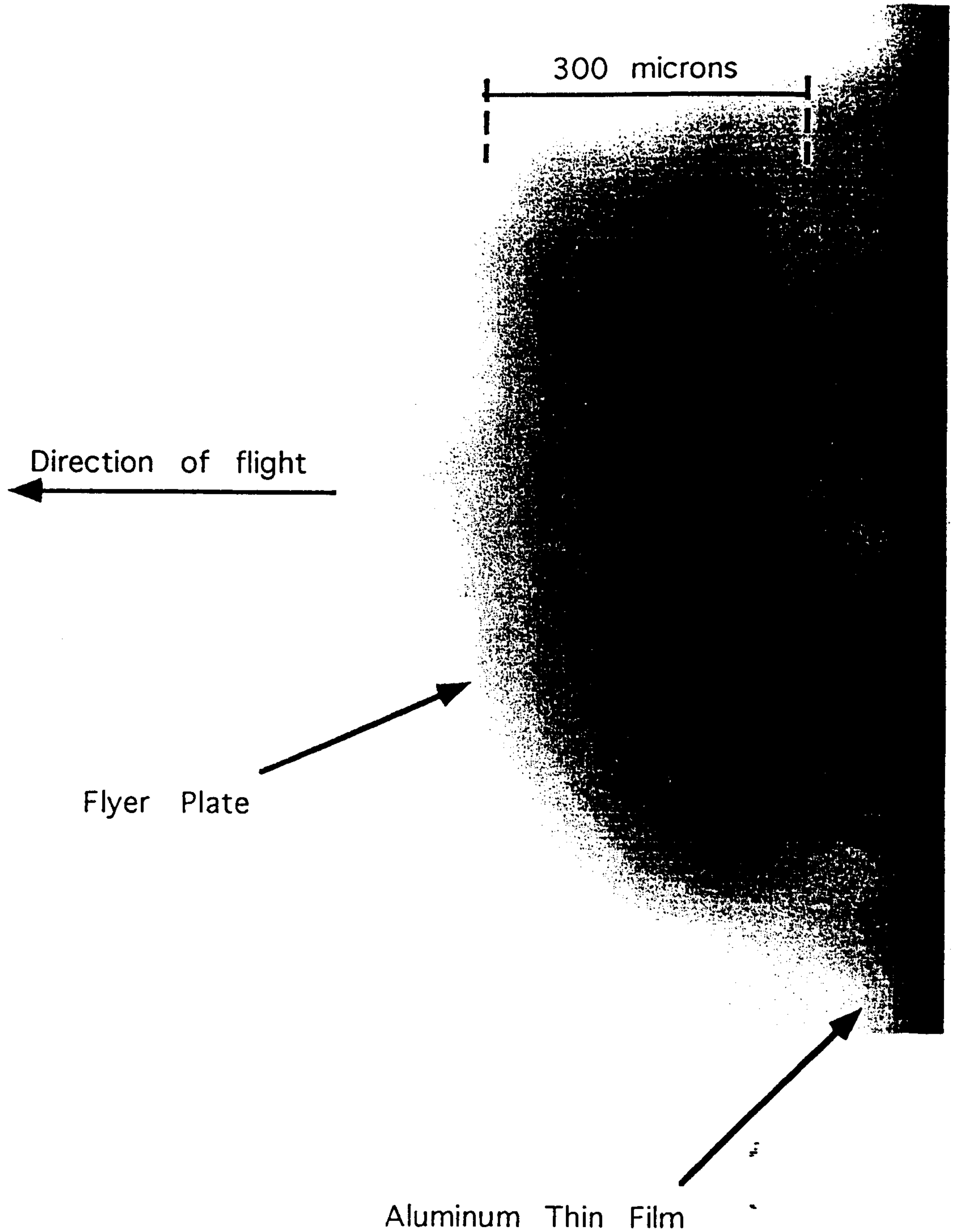
300 microns
Direction of flight
Flyer Plate
Aluminum Thin Film

Figure 2